

**AMINOCYCLOPENTADIENYL RUTHENIUM COMPLEXES**  
**AND PREPARATION THEREOF**

**Field of the Invention**

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The present invention relates to a novel ruthenium complex which is a remarkably effective catalyst in the racemization of chiral compounds.

**Background of the Invention**

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The production of one enantiomeric form of a chiral compound is often required in the pharmaceutical and other chemical industries and the desired enantiomer is obtained via resolution of its racemate. In such a process it is essential from the economic point of view to convert the unwanted enantiomer back to the racemic form and recycled.

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In the racemization step, ruthenium complexes such as [(*p*-cymene)RuCl<sub>2</sub>]<sub>2</sub> and (η<sup>5</sup>-Ph<sub>4</sub>C<sub>4</sub>CO)<sub>2</sub>H(μ<sup>-</sup>H)(CO)<sub>4</sub>Ru<sub>2</sub> (Shvo catalyst) are used as a catalyst. However, the ruthenium cymene complex exhibits a slow racemization reaction at room temperature, and Shvo catalyst which exists in the form of a dimer must be activated at a high temperature and it also requires the use of a hydrogen-transfer agent, e.g., the corresponding ketone to the alcohol in case a chiral alcohol is to be racemized (Y. Shvo *et al*, *Organometallics*, 8, 162, 1989).

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**Summary of the Invention**

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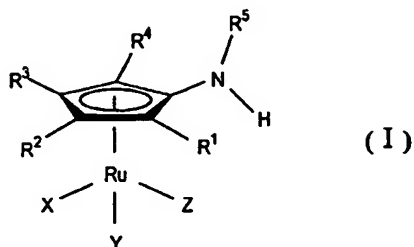
Accordingly, it is an object of the present invention to provide a novel compound which can be used as an effective catalyst in the racemization of chiral alcohols under a mild condition.

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It is another object of the present invention to provide a process for the preparation of said compound.

In accordance with one aspect of the present invention, there is

provided a ruthenium complex of formula( I ):



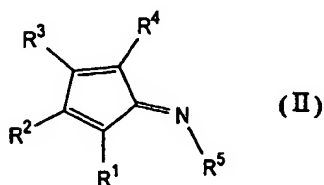
5 wherein:

$R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are each independently phenyl, substituted phenyl or  $C_{1-5}$  alkyl;

$R^5$  is hydrogen, phenyl, substituted phenyl,  $C_{1-5}$  alkyl, substituted  $C_{1-5}$  alkyl,  $C_{3-7}$  cycloalkyl,  $C_{2-5}$  alkenyl or  $C_{2-5}$  alkynyl; and

10 X, Y and Z are each independently hydrogen, halogen, carbonyl or  $PR^5_3$ .

Further, in accordance with another aspect of the present invention, there is provided a process for the preparation of the ruthenium complex of Formula( I ), which comprises reacting a compound of Formula( II ) and a  
15 ruthenium compound, such as  $Ru_3(CO)_{12}$ ,  $RuCl_2(CO)_2(PR^5_3)_2$ ,  $[RuCl_2(CO)_3]_2$ ,  $RuCl_2(PR^5_3)_3$ , and  $RuCl_3$  in a solution containing a haloform:



20 wherein:

$R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$  and  $R^5$  have the same meanings as defined above.

### Detailed Description of the Invention

25 In the compound of Formula( I ) of the present invention, the

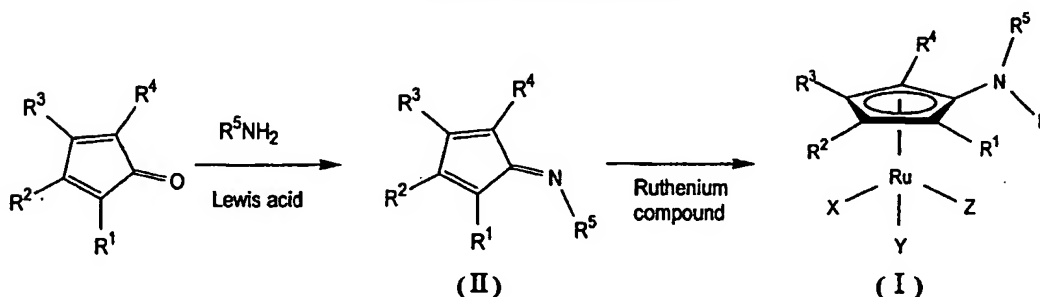
substituent of the substituted phenyl is at least one selected from the group consisting of C<sub>1-5</sub> alkyl, cycloalkyl, alkenyl, alkynyl, alkoxy, halogen, nitro, nitroso, amino, aminocarbamyl, hydroxy, mercapto and C<sub>1-5</sub> alkylthio, and the substituent of the substituted C<sub>1-5</sub> alkyl is at least one selected from the group consisting of aryl, C<sub>1-5</sub> alkoxy, halogen, nitro, nitroso, amino, aminocarbamyl, hydroxy, mercapto and C<sub>1-5</sub> alkylthio.

In Formula( I ) of the present invention, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> or R<sup>4</sup> is preferably a phenyl or C<sub>1-5</sub> alkyl group, R<sup>5</sup> is preferably hydrogen, a phenyl or substituted phenyl group, a C<sub>1-5</sub> alkyl or substituted C<sub>1-5</sub> alkyl group or a C<sub>3-7</sub> cycloalkyl group, and X, Y and Z substituents are each preferably hydrogen, halogen, carbonyl, or a phosphine group.

The ruthenium complex of Formula( I ) of the present invention may be prepared according to Reaction Scheme A:

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#### Reaction Scheme A



wherein:

R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, X, Y and Z have the same meanings as defined in formula( I ) above.

Namely, a cyclopentadienone derivative such as tetraphenylcyclopentadienone is reacted in an aprotic solvent with a primary amine in the presence of a Lewis acid to obtain an imine compound of Formula( II )(Step 1). Then, the imine compound of Formula( II ) is reacted with a ruthenium compound having X, Y and Z groups, such as Ru<sub>3</sub>(CO)<sub>12</sub>, RuCl<sub>2</sub>(CO)<sub>2</sub>(PR<sup>5</sup>)<sub>2</sub>, [RuCl<sub>2</sub>(CO)<sub>3</sub>]<sub>2</sub>, RuCl<sub>2</sub>(PR<sup>5</sup>)<sub>3</sub>, or RuCl<sub>3</sub> in a solvent, preferably a haloform to obtain the ruthenium complex of Formula( I ) of the

present invention(Step 2).

Representative examples of the primary amine used in Step 1 are ammonia, methylamine, ethylamine, propylamine, butylamine, pentylamine, isobutylamine, isopropylamine, t-butylamine, cyclopropylamine, cyclobutylamine, cyclopentylamine, aniline, toluidine and benzylamine. Also used in the present invention is a conventional Lewis acid, commonly known in the art, including  $\text{TiCl}_4$ ,  $\text{AlCl}_3$ ,  $\text{BF}_3$  and  $\text{SnCl}_4$ .

Representative examples of the aprotic solvent are toluene, benzene, hexane, oxane, tetrahydrofuran, diethyl ether, diisopropyl ether, t-butylmethyl ester, ethyl acetate, acetonitrile, acetone, dichloromethane, chloroform and carbon tetrachloride.

In Step 1, the primary amine, the Lewis acid and the aprotic solvent may be used in amounts of 1 to 7 molar equivalents, 0.1 to 3 molar equivalents and 2 to 20 folds (v/v), respectively, based on the starting cyclopentadienone derivative, and the reaction may be conducted at a temperature in the range of  $50^\circ\text{C}$  to  $150^\circ\text{C}$ .

In Step 2, the solvent may be chloroform, bromoform or fluoroform, and the amount of the imine compound of Formula(II) may be 1 to 3 mole equivalents based on the ruthenium compound. The reaction may be conducted at a temperature in the range of  $40^\circ\text{C}$  to  $120^\circ\text{C}$ .

The ruthenium complex of Formula(I) of the present invention is useful particularly in the racemization reaction of a secondary alcohol. The racemization may be carried out by adding the complex of Formula(I) of the present invention, together with a base, to a secondary alcohol having a chiral center in an aprotic solvent and agitating the resulting mixture at room temperature for about 30 minutes under an inert atmosphere. The base may be an inorganic base such as  $\text{LiOH}$ ,  $\text{KOH}$ ,  $\text{NaOH}$ ,  $\text{tBuOK}$  and  $\text{Na}_2\text{CO}_3$  or an organic base such as triethylamine, diisopropylethylamine, DBU (1,8-diazabicyclo[5.4.0]undec-7-ene), DBN (1,5-diazabicyclo[4.3.0]non-5-ene), while the aprotic solvent may be toluene, hexane, benzene, tetrahydrofuran, dioxane, dialkyl ether, alkyl acetate, acetonitrile, acetone, dichloromethane, chloroform or carbon tetrachloride. As the solvent, a water-immiscible

alcohol having four or more carbon atoms may also be used.

In the racemization reaction, the complex of Formula( I ) of the present invention and the base may be used in amounts of  $10^{-6}$  to 0.05 and  $10^{-6}$  to 0.06 equivalent amounts, respectively, based on the chiral compound  
5 to be racemized.

The following Examples are included to further illustrate the present invention without limiting its scope.

### Synthesis of ruthenium complexes

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**Example 1: Synthesis of N-isobutylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl chloride**

#### **Step 1) Synthesis of N-isobutyl-2,3,4,5-tetraphenylcyclopentadieneimine**

15 3g (7.8mmol) of tetraphenylcyclopentadienone and 3.49 ml (35.1mmol) of isobutylamine were dissolved in 50 ml of toluene and 0.7 ml(5.85mmol) of  $\text{TiCl}_4$  was added thereto at  $0^\circ\text{C}$ . The resulting mixture was agitated for 30 minutes at room temperature and then refluxed for 12 hours. The reaction mixture was cooled and ether was added thereto to  
20 induce solid precipitation. The resultant solid was filtered and dried to obtain 2.3g of the title compound.

m. p.:  $158^\circ\text{C}$ ;

$^1\text{H}$  NMR( $\text{CDCl}_3$ ): 7.25-7.18 (m, 10H), 7.09-7.00(m, 6H), 6.85(d,  $J=6.6$  Hz, 2H), 6.78(m,  $J=6.6$  Hz, 2H), 3.36(d,  $J=6.5$  Hz, 8H), 1.83(m, 1H),  
25 0.79(d,  $J=6.6$  Hz, 2H)

**Step 2) Synthesis of N-isobutylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl chloride**

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1g (2.4mmol) of the compound prepared in Step1 and 1g (1.6mmol) of  $\text{Ru}_3(\text{CO})_{12}$  were dissolved in 8ml of chloroform and reacted under an

argon atmosphere at 90°C for 5 days. The reaction mixture was cooled, concentrated and the residue was purified by column chromatography (column: silica gel, eluent: from hexane/ethylacetate of 8:1 to dichloromethane; gradient) to obtain 0.7g of the title compound

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m. p.: 151~152°C(dec.);

<sup>1</sup>H NMR(CDCl<sub>3</sub>): 7.58-7.56(m, 4H), 7.38-7.33(m, 6H), 7.09(dd, J=7.1 Hz, 2H), 7.02-7.91(m, 8H), 4.36(t, J=5.7 Hz, 1H), 2.56(t, J=6.4, 2H), 1.39(m, 1H), 0.57(d, J=6.7 Hz, 6H);

10 <sup>13</sup>C NMR(CDCl<sub>3</sub>): 198.6, 144.1, 133.7, 132.1, 130.7, 130.6, 129.1, 128.9, 128.4, 127.9, 101.6, 83.7, 52.1, 29.3, 20.1

**Example 2: Synthesis of N-isopropylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl chloride**

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**Step 1) Synthesis of N-isopropyl-2,3,4,5-tetraphenylcyclopentadieneimine**

20 The procedure of Step1 of Example 1 was repeated using 2.1g of isopropylamine in place of isobutylamine to prepare the title compound.

m. p.: 223°C;

<sup>1</sup>H NMR(CDCl<sub>3</sub>): 7.25-6.75 (m, 20H), 4.08-4.00 (m, 1H), 1.04(d, J=3 Hz, 6H);

25 <sup>13</sup>C NMR(CDCl<sub>3</sub>): 165.8, 137.6, 131.9, 130.2, 129.8, 128.2, 127.8, 127.4, 127.2, 127.1, 126.5, 52.3, 24.3

**Step 2) Synthesis of N-isopropylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl chloride**

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The procedure of Step2 of Example 1 was repeated using the compound prepared in Step1 to prepare the title compound.

m. p.: 197 °C(dec.);

<sup>1</sup>H NMR(CDCl<sub>3</sub>): 7.57-6.91(m, 20H), 4.20(d, J=4.1 Hz, 1H), 3.3-3.23(m,1H), 0.86(d, J=3.2 Hz, 6H);

5       <sup>13</sup>C NMR(CDCl<sub>3</sub>): 198.4, 144.8, 133.7, 131.9, 130.6, 128.9, 128.7, 128.2, 127.7, 101.4, 81.7, 45.6, 25.2

**Example 3: Synthesis of N-isobutylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl hydride**

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90mg (0.14mmol) of N-isopropyl-2,3,4,5-tetrabutylcyclopentadienyl ruthenium dicarbonyl chloride prepared in Example 1 and 45mg (0.42mmol) of sodium carbonate were dissolved in 6ml of isopropanol and reacted at 90 °C for 5 hours. The reaction mixture was filtered and the filtrate was  
15 concentrated to prepare 83mg of the title compound.

m. p.: 86.7 °C(dec.);

<sup>1</sup>H NMR(C<sub>6</sub>D<sub>6</sub>): 7.77(d, J=6.8 Hz, 4H), 7.57-7.54(m, 4H), 7.22-7.16(m, 8H), 7.04-7.01(m, 6H), 3.17(t, J=6.9 Hz, 1H), 2.66(t, J=6.5 Hz, 2H),  
20 1.49(m, 1H), 0.82(d, J=6.5 Hz, 6H);

<sup>13</sup>C NMR(C<sub>6</sub>D<sub>6</sub>): 203.6, 133.9, 133.7, 132.9, 131.7, 129.2, 129.0, 128.7, 106.6, 92.1, 61.2, 29.2, 20.8

**Example 4: Synthesis of N-isopropylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl hydride**

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The procedure of Example 3 was repeated using N-isopropyl-2,3,4,5-tetrapropylcyclopentadienyl ruthenium dicarbonyl chloride prepared in Example 2 to prepare the title compound.

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m. p.: 140 °C(dec.);

<sup>1</sup>H NMR(C<sub>6</sub>D<sub>6</sub>): 7.57-6.73(m, 20H), 2.99-2.93(m, 1H), 2.57(d, J=4.6

Hz, 1H), -9.14(s, 1H);

<sup>13</sup>C NMR(C<sub>6</sub>D<sub>6</sub>): 203.6, 134.1, 133.4, 132.9, 132.8, 130.2, 129.0, 127.8, 127.1, 106.3, 91.0, 50.1, 21.9

5 **Racemization of chiral secondary alcohol using ruthenium complexes of the present invention**

**Example 5**

1mg of potassium t-butoxide, 6mg of N-isobutylamino-2,3,4,5-  
10 tetrabutylcyclopentadienyl ruthenium dicarbonyl chloride prepared in Example 1 and 30μl of (S)-1-phenylethanol (>99% ee) were dissolved in 1ml of toluene and was agitated at room temperature for 30 minutes under an argon atmosphere. The reaction mixture was filtered and the filtrate was concentrated. The optical purity of the product measured with a HPLC(High  
15 Performance Liquid Chromatograph) equipped with a chiral column was 2% ee.

**Example 6**

0.5μl of 0.5 M Na<sub>2</sub>CO<sub>3</sub>, 6mg of N-isobutylamino-2,3,4,5-  
20 tetraphenylcyclopentadienyl ruthenium dicarbonyl hydride prepared in Example 3 and 30μl of (S)-1-phenylethanol (>99% ee) were dissolved in 1ml of toluene and the procedure of Example 5 was repeated. The optical purity after the reaction was 11% ee.

25 **Example 7**

1mg of potassium t-butoxide, 6mg of N-isopropylamino-2,3,4,5-  
tetraphenylcyclopentadienyl ruthenium dicarbonyl chloride prepared in Example 2 and 30μl of (S)-1-phenylethanol (>99% ee) were dissolved in 1ml of one of the solvents listed in Table 1 and agitated for 30 minutes at  
30 room temperature under an argon atmosphere. The optical purity measured as in Example 5 is shown in Table 1.



Table 1

Solvent	Reaction time(hours)	Optical purity(%ee)
Toluene	0.5	0.0
methylene chloride	0.5	0.0
tetrahydrofuran	0.5	0.0
Acetone	0.5	24.7
toluene + vinyl acetate mixture(22:1)	1.0	6.8
No solvent	12.0	1.6

**Example 8**

- 5           The procedure of Example 6 was repeated using N-isopropylamino-2,3,4,5-tetraphenylcyclopentadienyl ruthenium dicarbonyl hydride prepared in Example 4. The optical purity after the reaction was 1.2%ee.

10           As the above results show, the ruthenium complexes of Formula( I ) according to the present invention can racemize a chiral secondary alcohol rapidly at room temperature in the absence of a hydrogen-transfer agent.

15           While the invention has been described with respect to the specific embodiments, it should be recognized that various modifications and changes may be made by those skilled in the art to the invention which also fall within the scope of the invention as defined by the appended claims.